

The Reactive Bridge: A Novel Solid-State Low Energy Initiator



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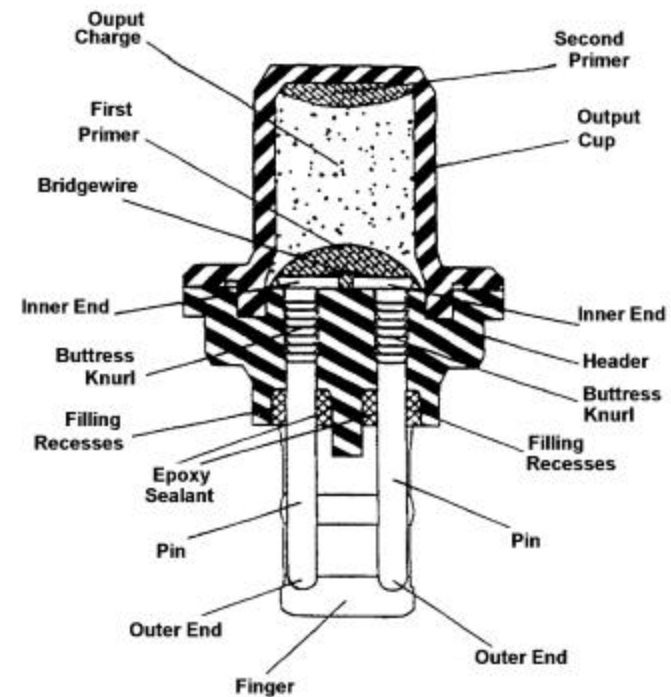
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Report Documentation Page

Report Date 16Apr2001	Report Type N/A	Dates Covered (from... to) -
Title and Subtitle The Reactive Bridge: A Novel Solid-State Low Energy Initiator		Contract Number
		Grant Number
		Program Element Number
Author(s) Baginski, Thomas A. ; Fahey, David		Project Number
		Task Number
		Work Unit Number
Performing Organization Name(s) and Address(es) Auburn University		Performing Organization Report Number
Sponsoring/Monitoring Agency Name(s) and Address(es) NDIA (National Defense Industrial Association) 211 Wilson BLvd., Ste. 400 Arlington, VA 22201-3061		Sponsor/Monitor's Acronym(s)
		Sponsor/Monitor's Report Number(s)
Distribution/Availability Statement Approved for public release, distribution unlimited		
Supplementary Notes Proceedings from The 45th Annual Fuze Conference, 16-18 April 2001 Sponsored by NDIA, The original document contains color images.		
Abstract		
Subject Terms		
Report Classification unclassified	Classification of this page unclassified	
Classification of Abstract unclassified	Limitation of Abstract UU	
Number of Pages 27		

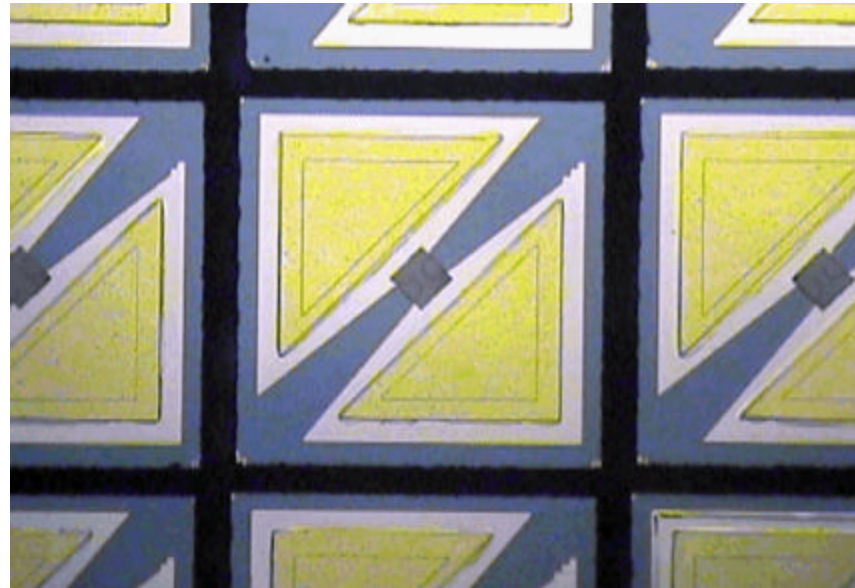
EED Structure

- Conductive Pins
- Header and Cup
- Bridgewire
- Primary Charge
- Output Charge



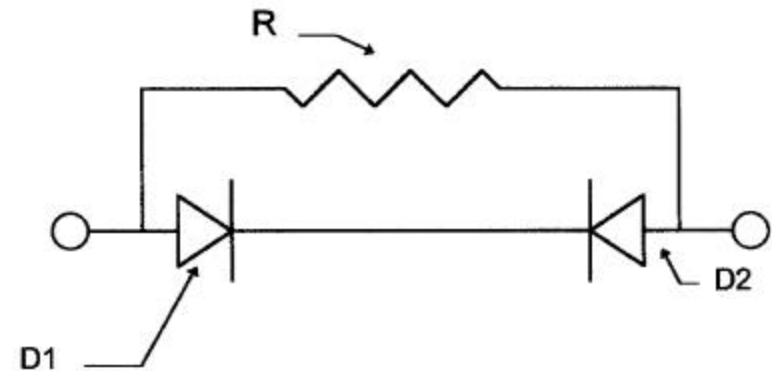
Reactive Bridge vrs. Bridgewire

- Faster Actuation ($<5\mu\text{sec}$)
- Lower Firing Energy ($<30\mu\text{J}$)
- Smaller Dimensions (Feature size $<20\mu\text{ms}$)
- Reliable Ignition Across Airgap
- Insensitive to ESD
- Fabricated with Conventional Microelectronic Processes



Design Model

- Resistive Heating Element (1Ω - 10Ω)
- Two PN Junction Diodes in Parallel for ESD Protection (Breakdown Voltage $\sim 4V \Leftrightarrow 20V$)



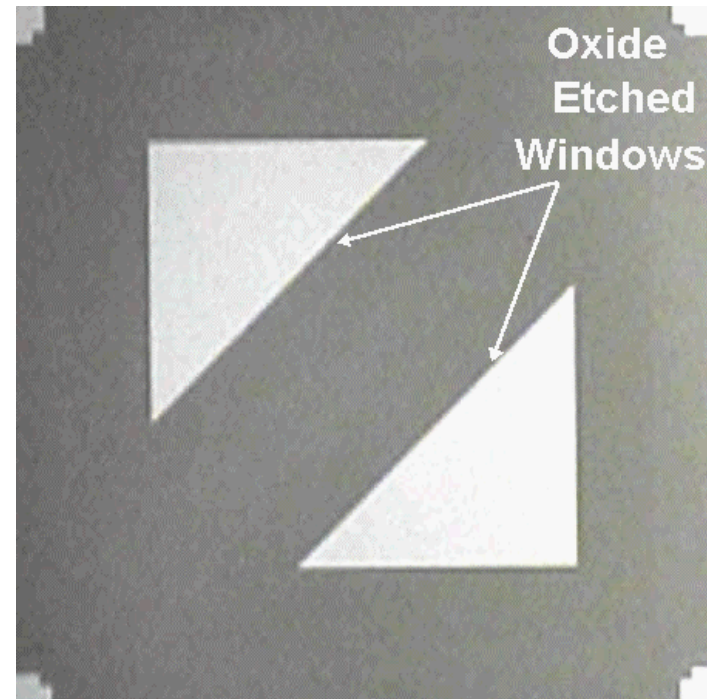
Composite Reactive Bridge Fabrication



- Utilizes Basic Fabrication Techniques
- Photolithography
- Wet Chemical Etching
- Sputtering and E-beam Metal Deposition
- Liftoff Process

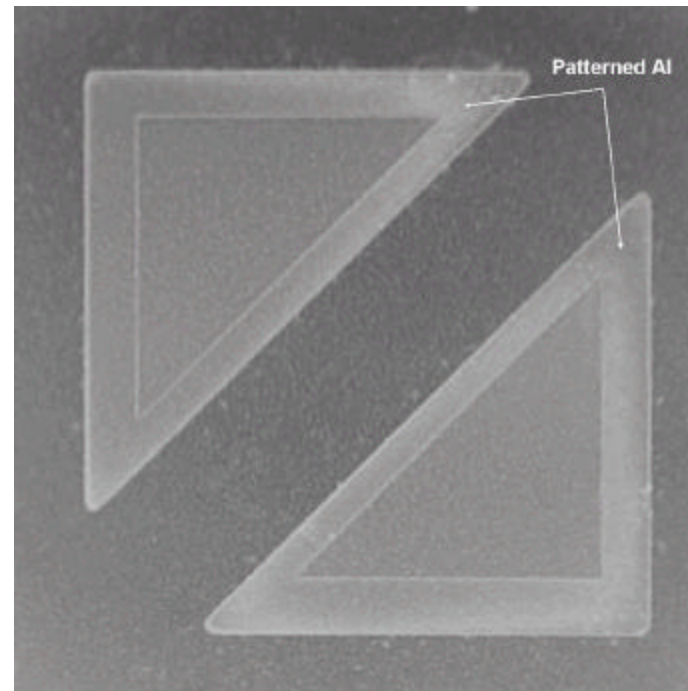
Implant and Diffusion

- Etch Oxide Window using BOE
- Typical Ion Implant
 - B
 - $Q = 5E15/cm^2$
 - Energy = 50keV
- Typical Drive-In
 - 1000°C, N₂
 - 15 minutes



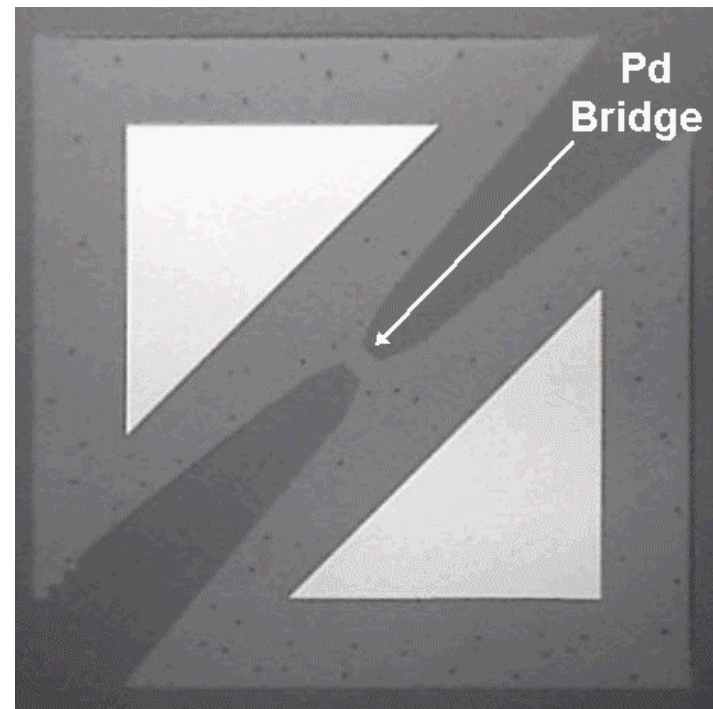
Aluminum Deposition

- Sputter $\sim 12,000\text{\AA}$ of Si/Al
- Mask off Window
- Etch Al with PAE
- Etch Residual Si
- Alloy Al at 450°C for 30 minutes



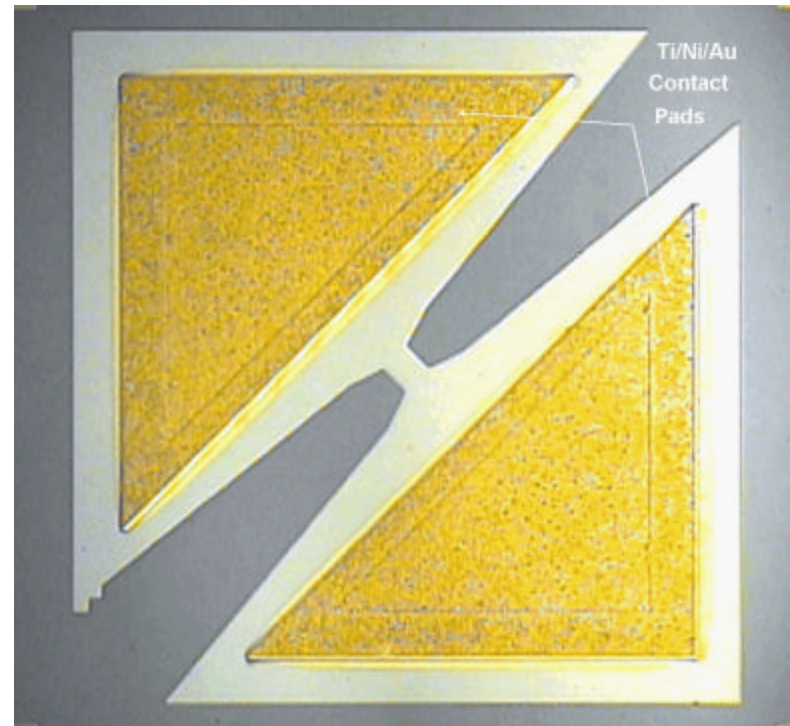
Palladium Deposition

- Mask and Develop
- Deposit
 - 500Å of Ti
 - 2000Å of Pd
- Liftoff
 - Ultrasonic and Acetone



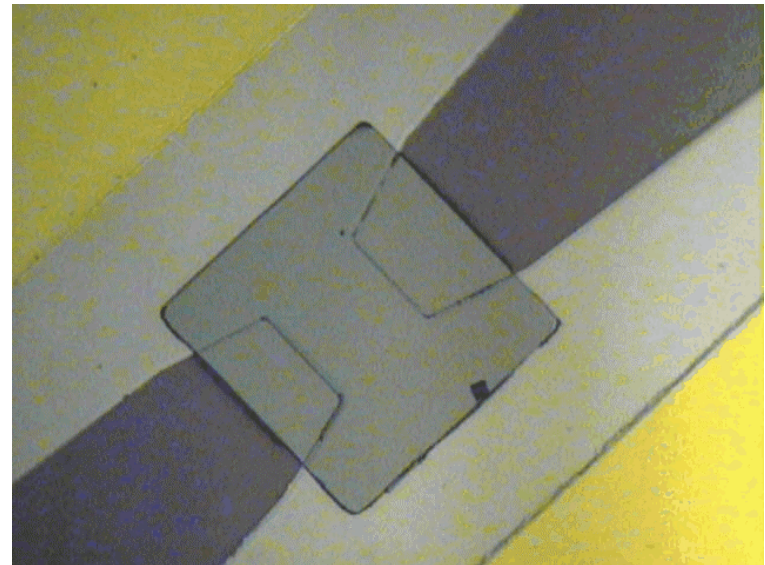
Gold Deposition

- Mask and Develop
- Deposit
 - 500Å of Ti
 - 1000Å of Ni
 - 2000Å of Au
- Liftoff
 - Ultrasonic and Acetone



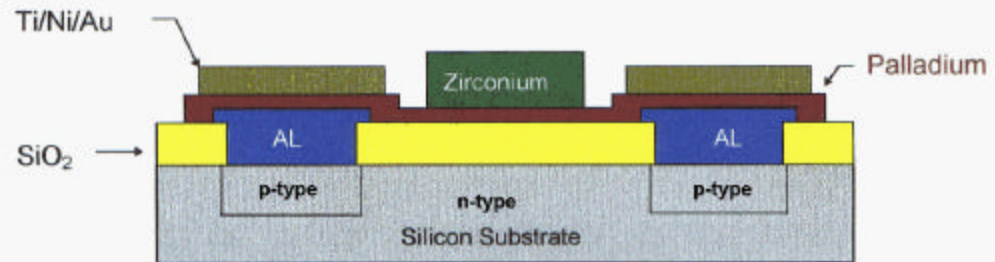
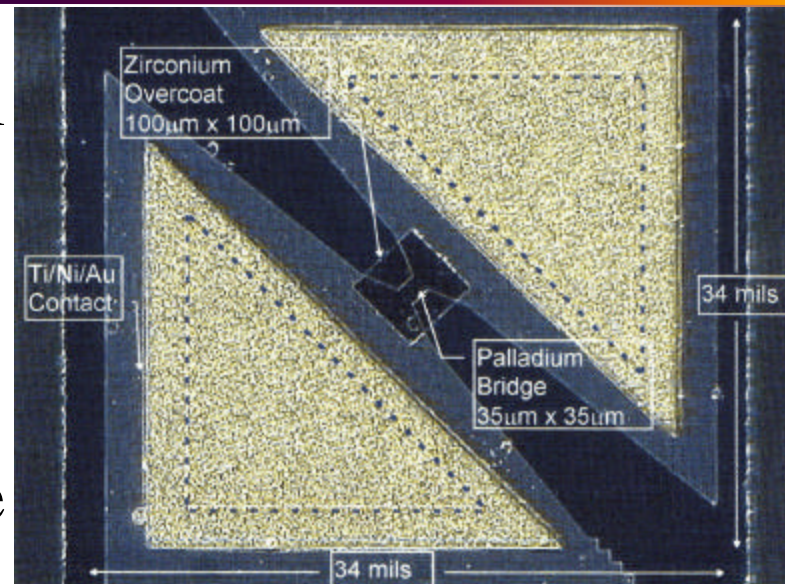
Zirconium Deposition/Reactive Overcoat

- Mask and Develop
- Deposit
 - 500Å of Ti
 - 10,000Å of Zr
- Additional Mass for Plasma Formation
- Chemically Reactive
- Liftoff
 - Ultrasonic and Acetone



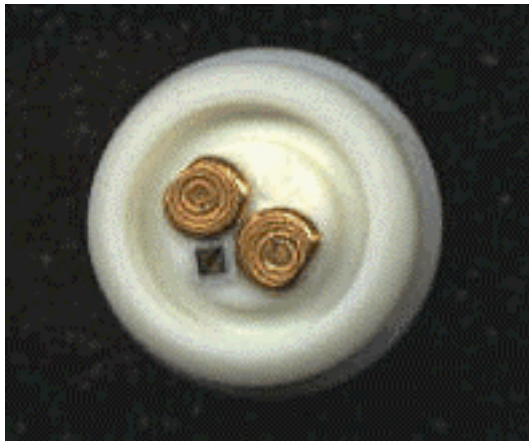
Typical Dimensions

- ~1mm x 1mm, overall size
- $15\mu\text{m}^2$ - $40\mu\text{m}^2$, varying bridge size
- $100\mu\text{m}^2$, overcoat size



Packaging

- ValoxDR48 Plastic Header
- Conducting Pins
- Output Cup



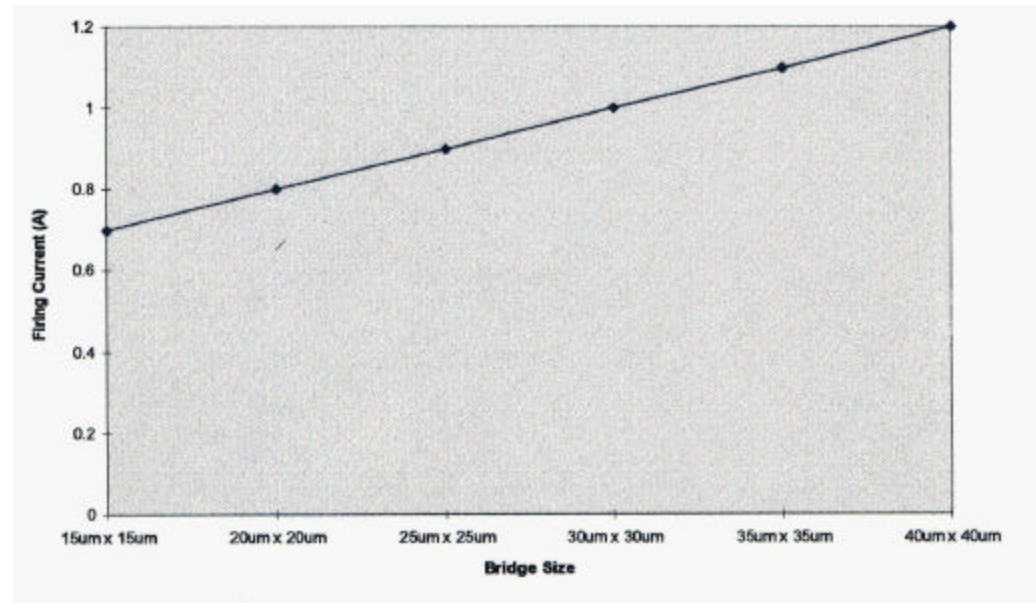
Design Validation Testing

- Firing Current
Proportional to Bridge
Size

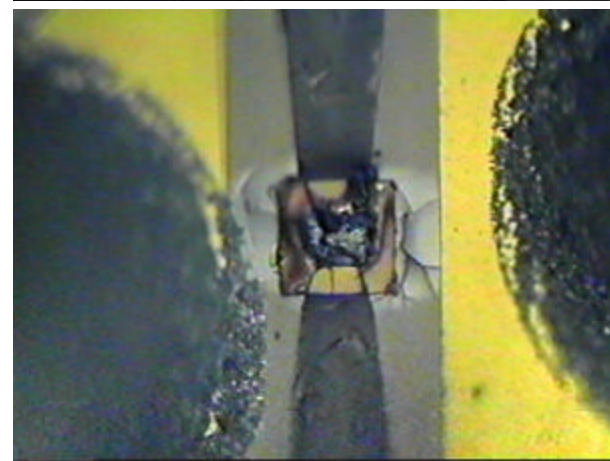
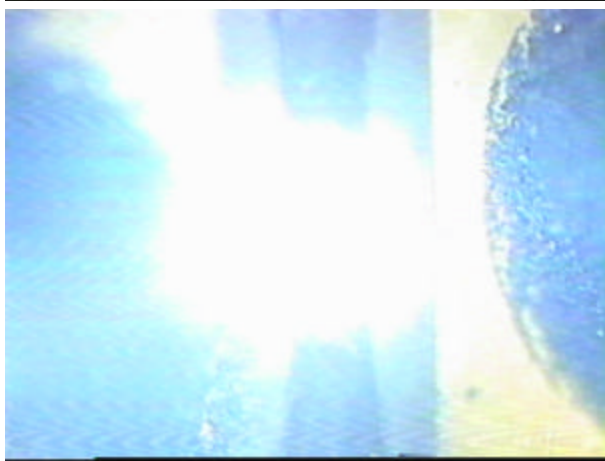
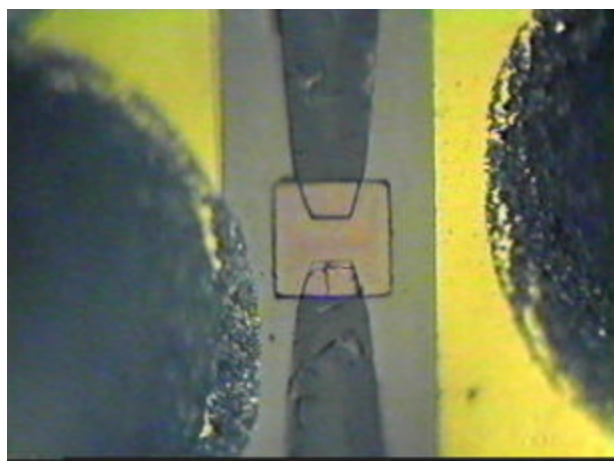
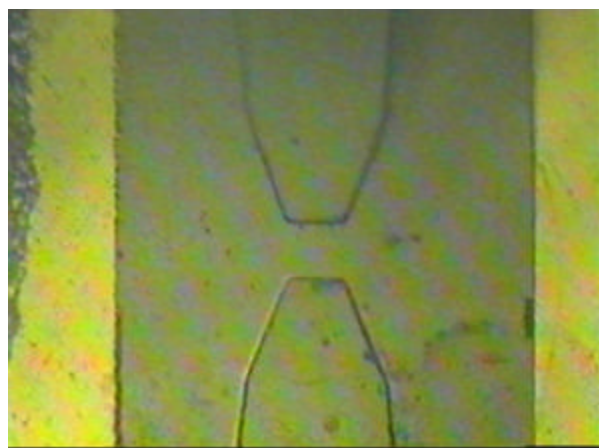
- Firing Energy,

$$Q = \int_0^t (I^2 R) dt$$

- I = Firing Current
- R = 2Ω (bridge)
- t = .1msec

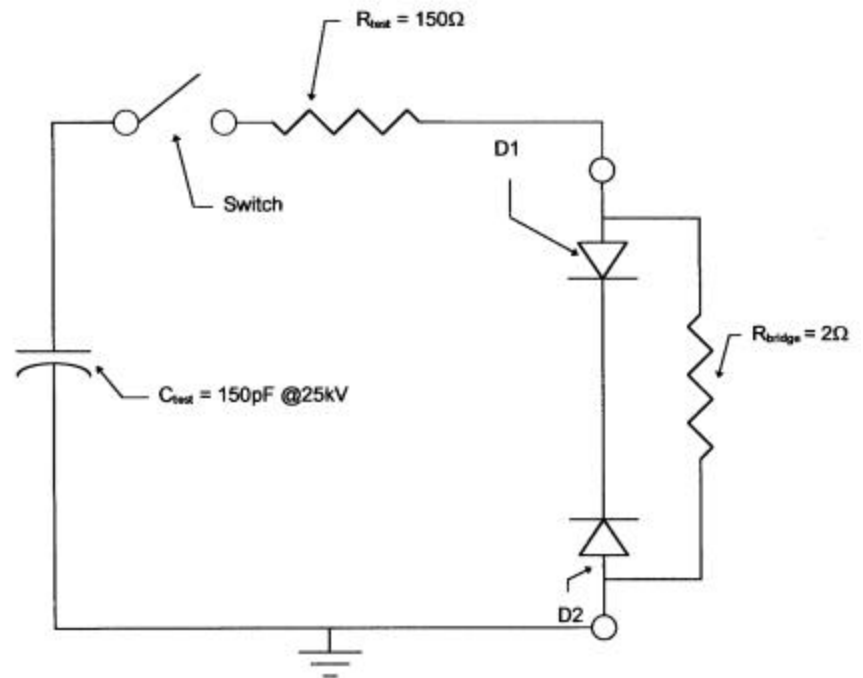


Firing Results With Without Overcoat 2mF@30V



ESD Test Setup

- 150pF Capacitor
Charged to 25kV
- Series Resistor of
150Ω
- Close Switch
- Repeat 5 times



Environmental Test Setup



- 320 Parts
- High Temp, 144 hrs @ 107°C
- Thermal Shock and Humidity
 - 6 cycles(-40°C and 107°C) for 12 hrs
- Random Vibration
 - Method S14:4 category I
 - 3 perpendicular axis, -40°C, 21°C, and 90°C

All Fire/No Fire Data



All Fire / No Fire Summary

Group	Bond	AF @ 1ms, 99.999% @ 95% Confidence -40C	AF @ 1ms, 99.999% @ 95% Confidence +21C	NF @ 10s, 99.999% @ 95% Confidence +90C	NF @ 10s, 99.999% @ 95% Confidence +21C
Baseline	Wirebond	1.037A	NA	.583A	NA
Post Serial Environ.	Wirebond	1.039A	NA	.617A	NA
Baseline	Conductive Epoxy	1.026A	NA	.613A	NA
Post Serial Environ.	Conductive Epoxy	1.040A	0.997A	.613A	.605A

Validation Testing Results



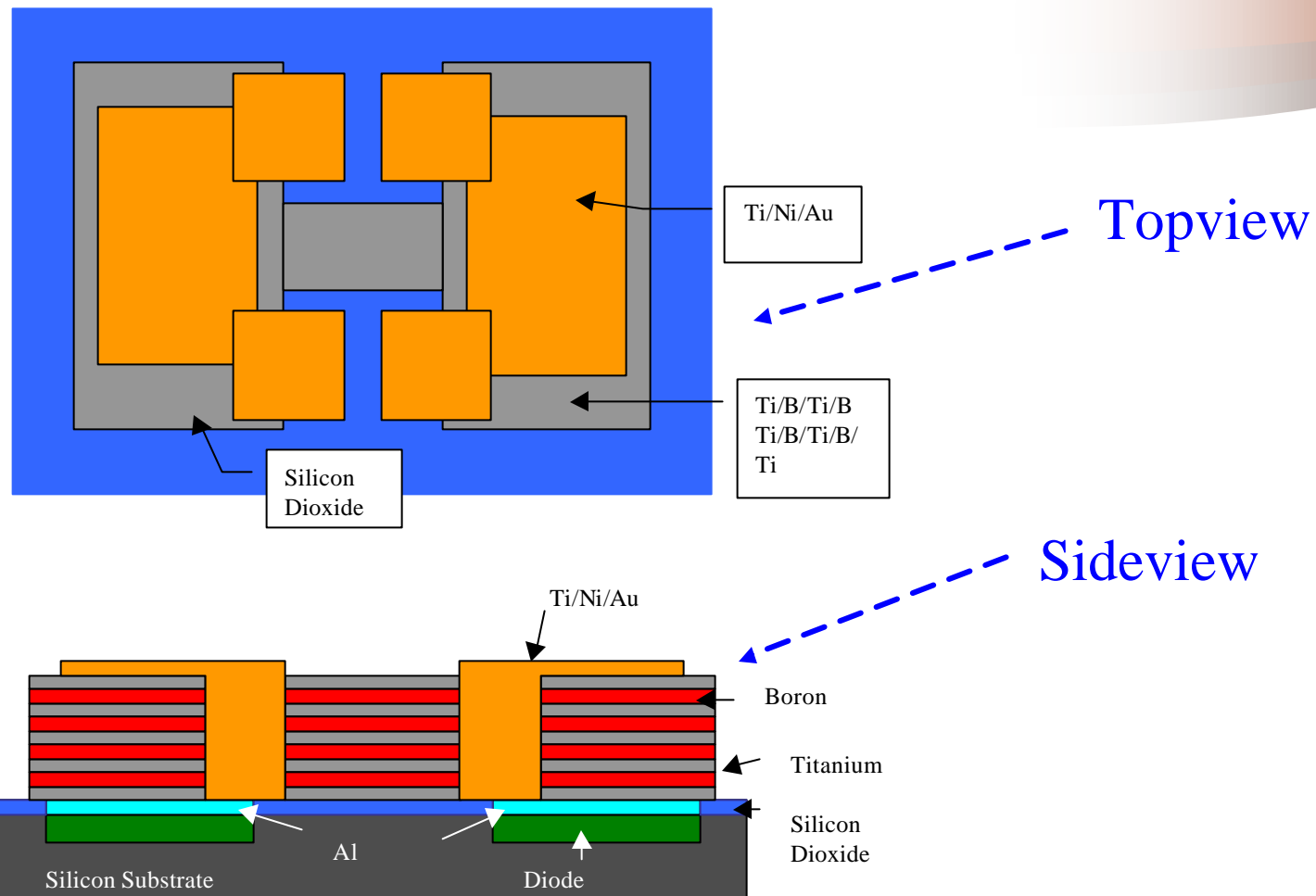
- Results Extremely Positive
- 1.2A, 1msec all-fire
- 0.5A, 10s no-fire
- 99.999% reliability, 95% confidence
- Time to Peak Pressure, < 1ms

The Laminated Reactive Bridge



- Structure employs laminations of B/Ti
- Exothermic inter-metallic alloy
- No oxidizer required
- $2\text{B} + \text{Ti} \Rightarrow 1320\text{cal/gm}$

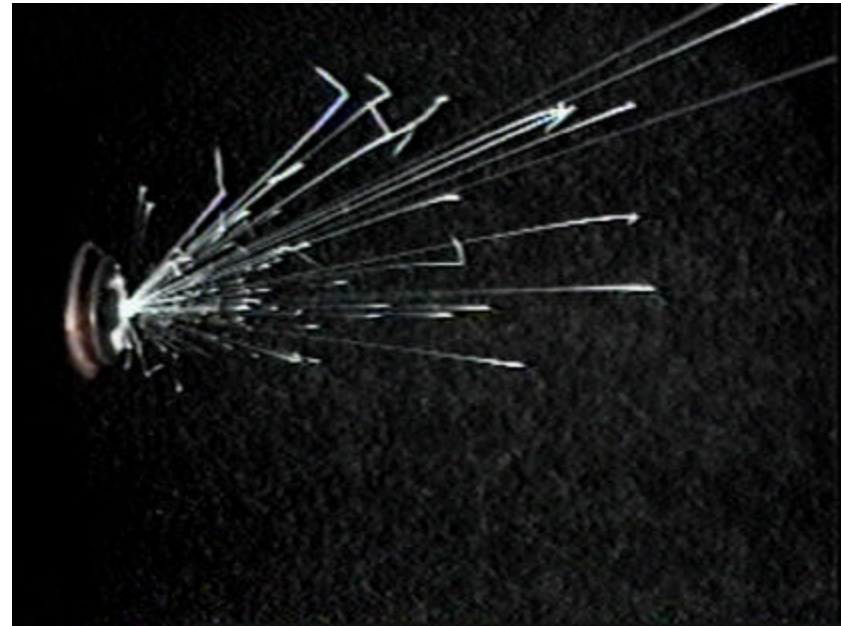
Laminated Reactive Bridge



Sample Firing Of Laminated 110mm Bridge 35mF@30V

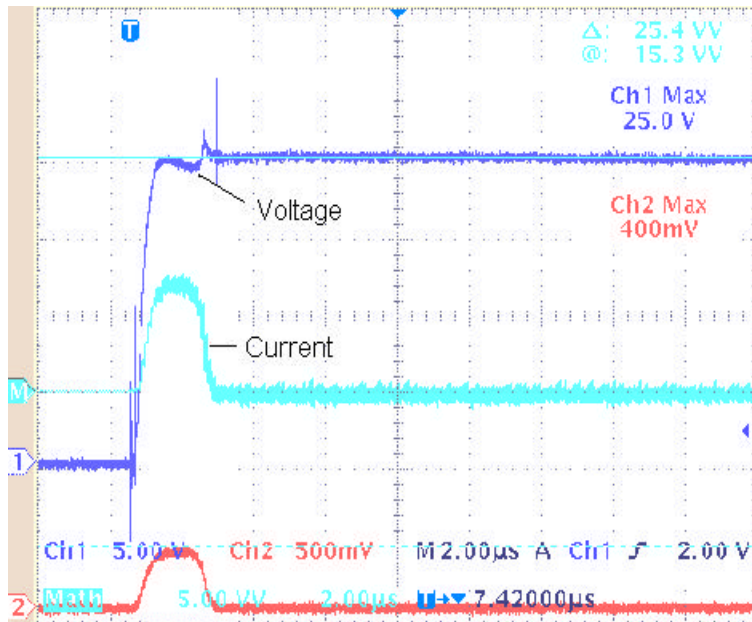


← 4cm →

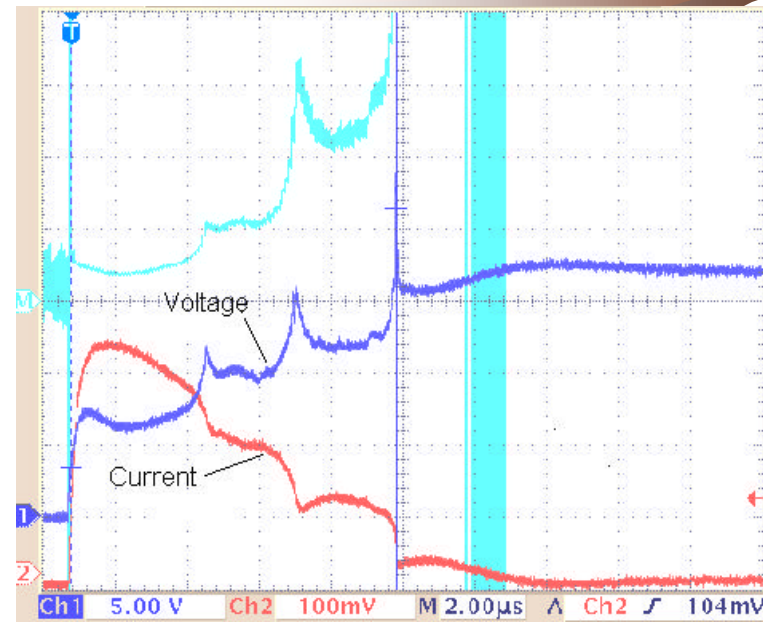


← 4cm →

Firing Current Waveforms

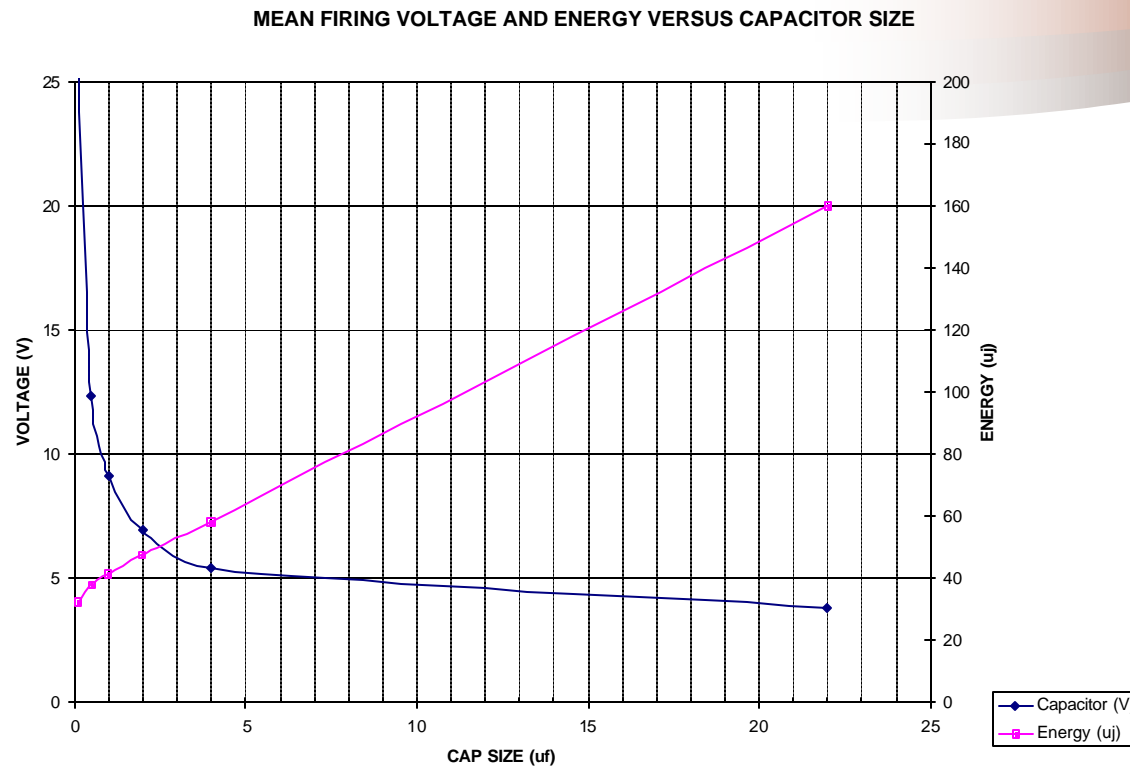


Typical Firing Trace of a Composite Bridge
(30μm bridge)



Typical Firing Trace of a Laminate Bridge
(30μm bridge)

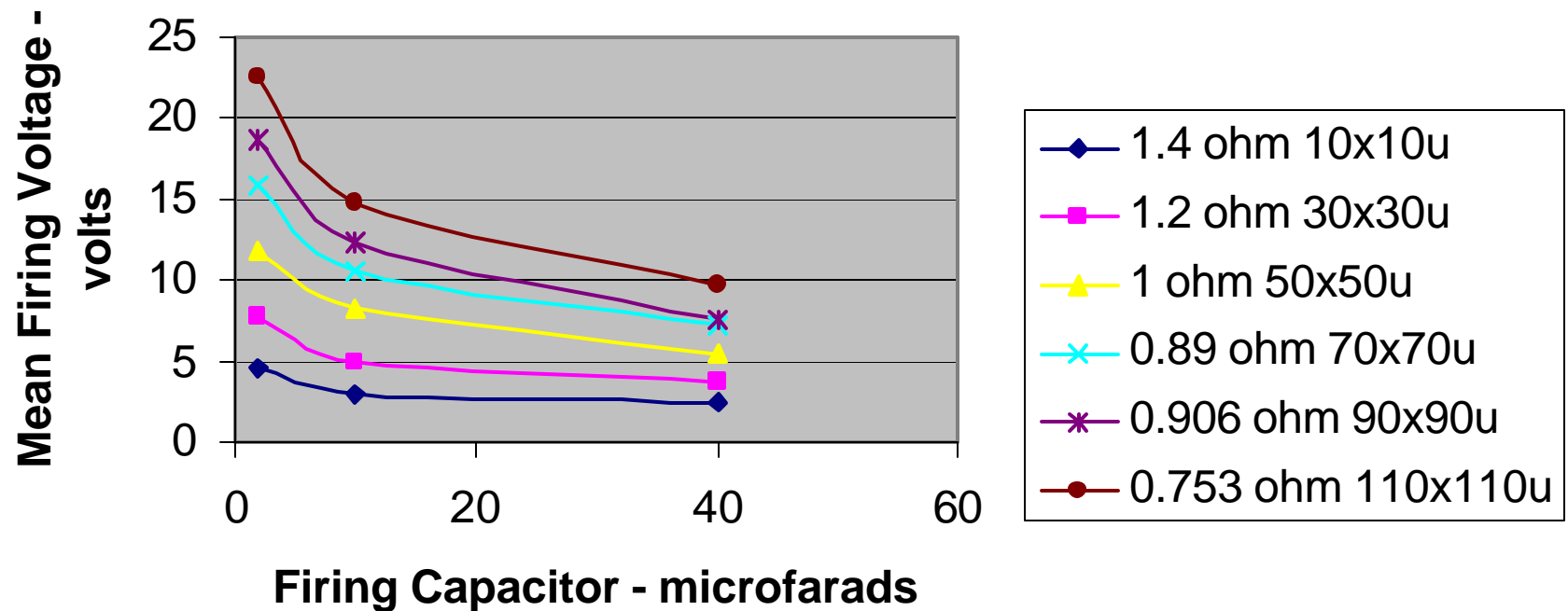
Firing Characteristics of Laminated Bridge with 5W ESR



A plot of firing voltage and energy for a 20 μm Laminated bridge

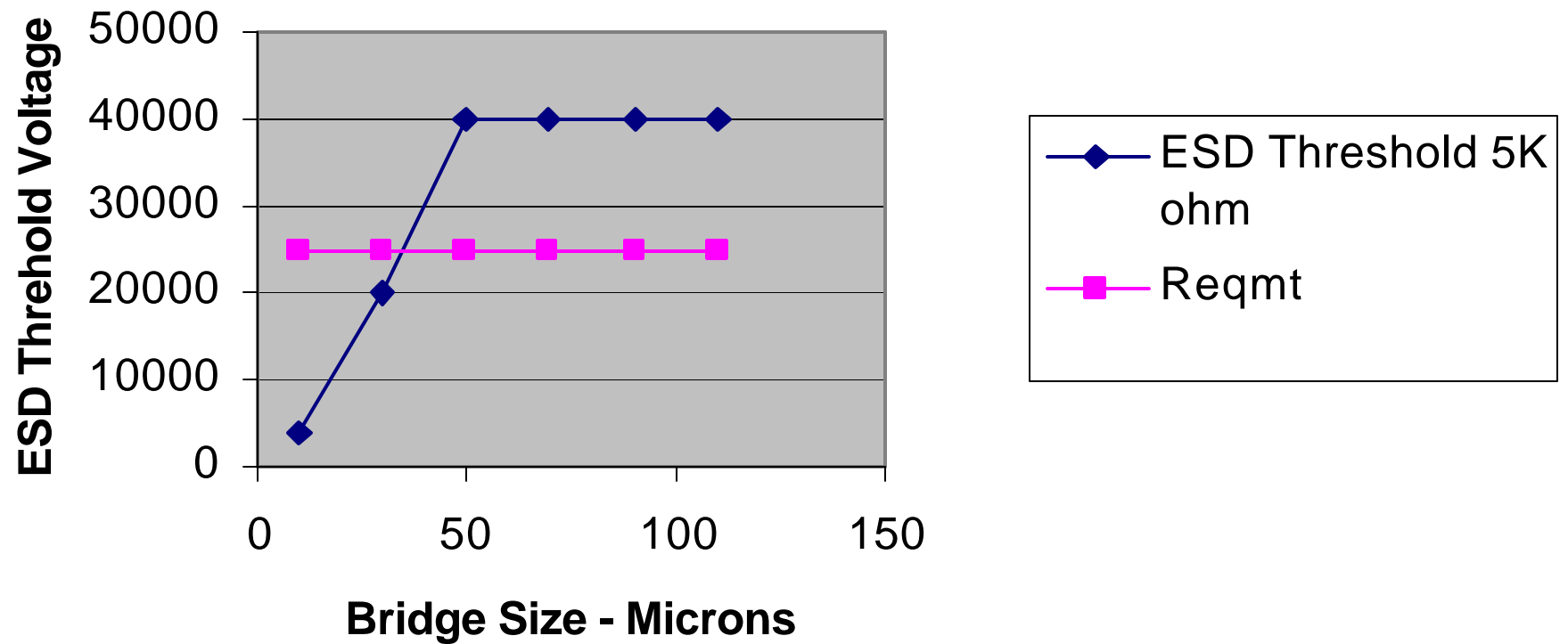
Firing Data for Laminated Bridge

**Reactive SCB Mean Firing Voltage Vs
Capacitance & Bridge Size**

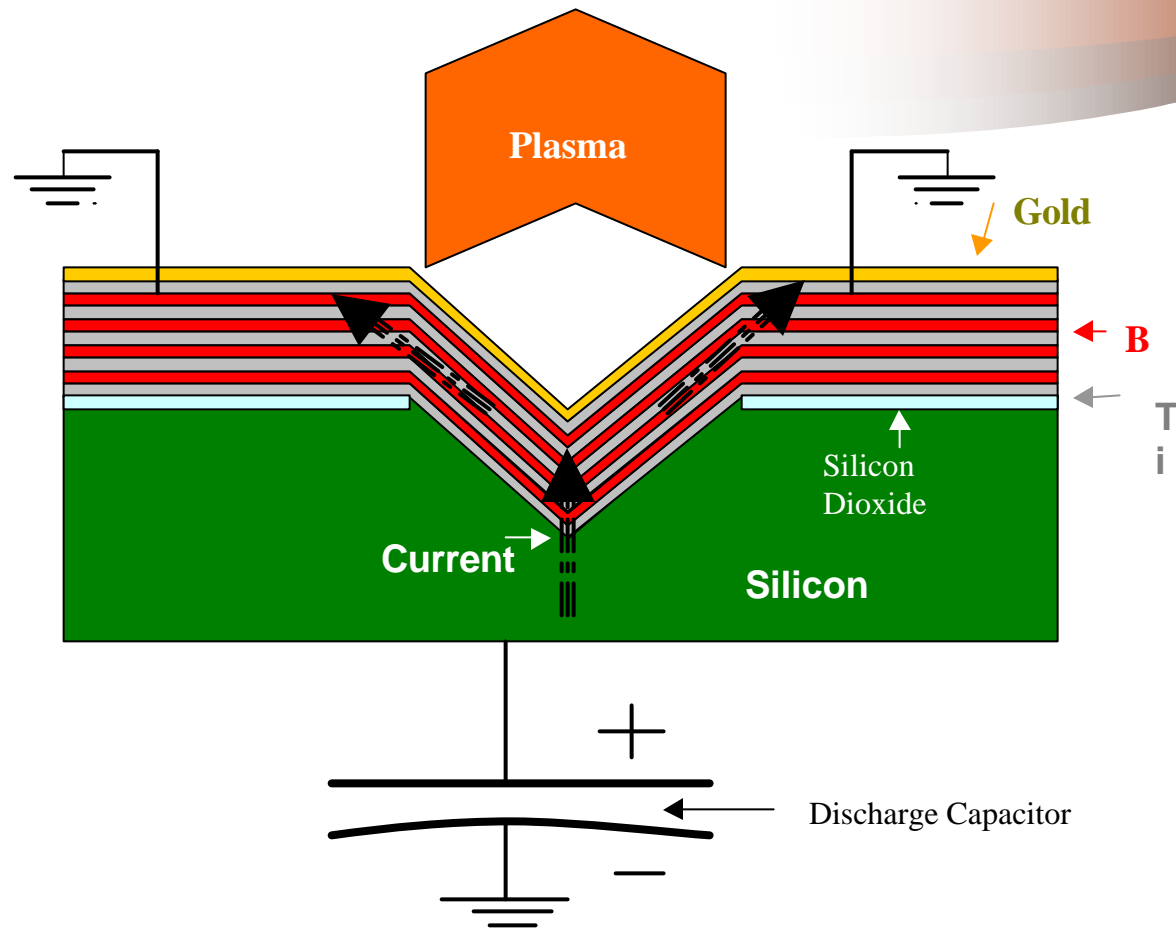


ESD Results for Laminated Bridge

ESD Threshold Voltage (500pf 5K ohm)



Integrated Shaped-Charge



Conclusion



- Devices Fabricated Using Conventional Techniques
- Demonstrates Lower Firing Energy
- Diodes Protect Against ESD Events
- Reliably Fires in Less Than 1 μ sec
- Plasma Output Capable of Jumping a Gap
- Very Economical for Large Volumes